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Government Of India
Patent Office
Todi Estates, 3rd Floor,
Lower Parel (West)
Mumbai – 400 013

THE PATENTS ACT, 1970

IT IS HEREBY CERTIFIED THAT, the annex is a true copy of Application and Provisional specification filed on 27/01/2003 in respect of Patent Application No. 96/MUM/2003 of STERLITE OPTICAL TECHNOLOGIES LIMITED, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharashtra, India, An Indian Company.

This certificate is issued under the powers vested in me under Section 147 (1) of the Patents Act, 1970.

Dated this 17th day of march 2004.

(N.K.GARG)
ASST. CONTROLLER OF PATENTS & DESIGNS.

Patent Application No. ----------- /MUM/2003
Dated - - - - - - - day of - - - - - - - - - 2003

FORM 1
THE PATENTS ACT, 1970
[39 OF 1970]
APPLICATION FOR GRANT OF A PATENT
[See Sections 7 and 54 and Rule 33A]

ORIGINAL

1 We
[a] STERLITE OPTICAL TECHNOLOGIES LIMITED
[b] E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India
[c] An Indian company

2 hereby declare –
[a] that, we are in possession of an invention titled, "Dispersion optimized fiber with higher spot area",
[b] that, the Provisional/Complete Specification relating to this invention is filed with this application,
[c] that, there is no lawful ground of objection to the grant of a patent to us.

3 Further declare that, the inventors for the said invention are:
[a] PRASAD, Shashikant,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

[a] DAS, Sthitadhi,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

[a] KUMAR, Nageswaran Senthil,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

[a] BHATIA, Sanjeet,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

[a] SINHA, Salaj,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

[a] KHANNA, Pankaj,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National.

4 We claim the priority from the application filed in conventional countries, particulars of which are as follows: Not Applicable.

5 We state that the said invention is an improved in or modification of the invention, the particulars of which are as follows and of which we are the applicant/patnetee:-
[a] Not Applicable

6 We state that the application is divided out of our application, the particulars of which are given below and pray that this application deemed to have been filed on - - - - - -under Section 1 of the Act.
[a] Not Applicable

7 That we are the assignees of the true and first inventors.

8 That our address for service in India is as follows:
REMFRY & SAGAR, Attorneys-at-Law, Remfry House at the Millennium Plaza, Section 27, Gurgaon – 122 002, National Capital Region, India.
Phone No. 91-124-280 6100, Fax No. 91-124-280 6101

9 Following declaration was given by the inventors:-
We,

[a] PRASAD, Shashikant,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

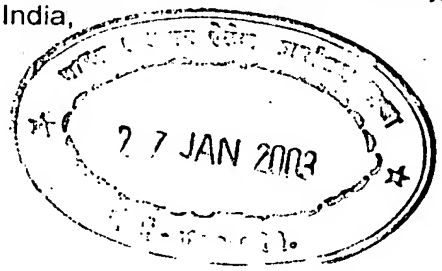
[a] DAS, Sthitadhi,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

[a] KUMAR, Nageswaran Senthil,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

[a] BHATIA, Sanjeet,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

[a] SINHA, Salaj,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National;

[a] KHANNA, Pankaj,
[b] of Sterlite Optical Technologies Limited, E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India,
[c] An Indian National.



the true and first inventors for this invention declare that the applicants herein are our assignee:-

Shashikant Prasad

Sthitadhi Das

Nageswaran Senthil Kumar

Sanjeet Bhatia

Salaj Sinha

Pankaj Khanna

10 That to the best of our knowledge, information and belief the fact and matters stated herein are correct and that there is no lawful ground of objection to the grant of patent to us on this application.

11 Following documents are attached with this application:

[a] Complete specification [3 copies];
[b] Drawings [3 copies];
[c] Statement and undertaking on Form 3;
[d] Form 5;
[e] Fee of Rs. 5,000/- (Rupees five thousand only) by cheque No. 263467 ---- dated - 22nd --- of - Jan. - 2003 payable to the "Controller of Patents, Mumbai at Mumbai.

We request that a patent may be granted to us for the said invention.

Dated this 22nd day of January, 2003.

भारत सरकार पेटेन्ट कार्यालय शाखा
27 JAN 2003
मुंबई - ४०० ०१२.

Signature:
Name: PANKAJ KHANNA
Designation: Chief Project Manager
For and on Behalf of the Applicant
[Sterlite Optical Technologies Limited]

To

The Controller of Patents,
The Patent Office, MUMBAI

FORM 2

THE PATENTS ACT 1970
[39 OF 1970]

PROVISIONAL SPECIFICATION

[See Section 10]

"DISPERSION OPTIMIZED FIBER WITH HIGHER SPOT AREA"

ORIGINAL

STERLITE OPTICAL TECHNOLOGIES LIMITED, of E-2, MIDC, Waluj, Aurangabad – 431 136, Maharastra, India, An Indian company.

The following specification describes the nature of the invention:-

TITLE OF THE INVENTION

Dispersion Optimized Fiber with Higher spot area

Technical Field of the Invention

The present invention relates to low dispersion, low dispersion slope and larger spot area, particularly it relates to dispersion-optimized fiber to provide low dispersion slope and high effective area between 1530 to 1565 nm (C-band) and 1565 to 1625 nm (L-band) transmissions. More particularly it relates to single mode dispersion optimized fiber, which is suitable for transmission of more channels of higher bandwidth over longer distance with more uniform chromatic dispersion and with lower power density over the third and forth window and yet has optimized mode field diameter to achieve low bending induced loss at 1550 nm and at the more critical 1625 nm wavelength.

Background Art of the Invention

Network capacity optical communication in the world is exploding. The growing bandwidth demand can be met by use of the new generation of dense wavelength division multiplexer, hereinafter referred to as DWDM, approach with low dispersion single mode optical fibers in the 1530-1565 nm (C-band) and in the 1565-1625 nm (L-band). The requirements of fiber have had to change to support these advances, especially the requirement for the higher spot area and the amount and uniformity (slope) of chromatic dispersion across these wavelengths. The DWDM approach enhances the effective data rate of an optical fiber link by increasing the number of wavelength channels within the wavelength band.

The bandwidth or the capacity of the Lightwave systems can be expanded in different ways. A. Increasing the number of wavelengths within the fiber (DWDM). B. Transmitting at a faster speed (Time division multiplexing) or C. By increasing number of fibers within the cable. Power requirements of the optical amplifier limits the more fiber counts within cable.

This is the fact that systems push the performance to the limit. Hence the roll of fiber in the system becomes critical. Dispersion must be balanced between the requirement for compensation and the suppression of non-linear effects. Effective area must be larger to reduce the non-linear effects without affecting the fiber performance. Dispersion slope must be low enough to reduce the inter channel spacing i.e., for all channels to propagate with a extremely low errors in bit rate.

Due to increasing complexity of the demands on fiber makes designer to think further to re-optimizing the refractive index profile, letting them to thinking for more complex designs. Complex designs are very sensitive to manufacturing process. Optical and material physics limits the combination of parameters, which can be achieved. The end product is the compromise, where each parameter is optimized to the best value, which can be achieved without adversely affecting performance of the critical attributes and system requirements. Insensitive system modeling is done with each varied parameters to understand its impact.

Need of the Invention:

Hence, there is a need to develop a dispersion and effective area optimized fiber, particularly single mode dispersion optimized fiber having as far as possible optimum low dispersion slope between 1530 to 1565 nm (C-band) and 1565 to 1625 nm (L-band) transmissions along with higher effective area, more particularly to develop a fiber which is suitable for transmission of higher bandwidth over longer distance with more uniform chromatic dispersion over the third and fourth window and yet has very high effective area and also to achieve low bending induced loss at 1550 nm and at the more critical 1625 nm wavelength.

Objects of the Invention

The most important object of the present invention is to make a complete disclosure of one fiber, which has low dispersion and low dispersion slope particularly between 1530 and 1565 nm wavelengths.

The object of the present invention is also to make a complete disclosure of the fiber, which has low dispersion slope and are suitable for long haul transmission.

Still another object of the present invention is to make a disclosure of the fiber, which has higher effective area at 1550 nm wavelength but also has optimized cut-off wavelength and mode field diameter.

Yet another object of the present invention is to make a disclosure of two fibers, which not only have high level of bend resistance but also has minimized non-linearities with optimum chromatic dispersion.

Brief Description of the Figures

The nature of the present invention is described with the help of accompanied figures, which are incorporated with a view to demonstrate the invention and its best mode of operation and are not intended to limit the scope of the present invention. The present invention is however, limited by the relation of refractive indices and their respective values and or by radii of various parts of the disclosed fiber as elaborated in the following description.

Fig 1 shows the key attributes of the fiber in accordance to the preferred embodiments of the present invention.

Fig 2a shows a cut section of the optical fiber in accordance to the preferred embodiments of the present invention.

Fig 2b shows the refractive index profile of the optical fiber shown in figure 2a in accordance to the present invention.

Fig 3 shows the chromatic dispersion along with waveguide dispersion of the optical fiber shown in figure 2a in accordance to the present invention.

Fig 4 shows the intensity distribution along the diameter of the presently disclosed fiber shown in figure 2a in accordance to the present invention.

Nature and Brief Disclosure of the invention

In accordance with the critical designing analysis carried out by the inventors, it appears that the main drawbacks and limitations of the prior art can be overcome by a fiber, which has chromatic dispersion 2.2 to 6.0 ps/nm.km and 4.0 to 11 ps/nm.km over the operating wavelength 1530 to 1565 nm (C-band) and 1565 to 1625 nm (L-band) wavelength respectively, a effective area of typically 72 micron^2 and a minimum dispersion slope of 0.075 ps/nm^2.km over the said wavelength regions. Therefore, in the present invention an attempt has been made to develop a fiber having such a refractive index profile and configuration which is not only easy to be achieved but also easy to be fabricated, wherein the said fiber will have chromatic dispersion and dispersion slope characteristics in or closer to said ranges or values.

With reference to the present invention the disclosed optical fiber shown in figure 2a, comprising of a center core 1, cladding 2, a ring core 3 and the outer glass region 4, wherein the first cladding 2 is provided onto the outer periphery of the center core 1, and the ring core 3 is provided onto the outer periphery of the second cladding 2, and said outer glass region 4 surrounds said ring core 3 [Figure 2a].

According to this invention the center core 1 and the ring core 3 having refractive indices higher than the outer glass 4. The refractive indexes of first cladding 2 is lower than the outer glass region 4 [Figure 2b]

The refractive index of the center core 1, cladding 2, ring core 3 and outer glass 4 are identified by the symbols n_1, n_2, n_3, and n_4 respectively. These refractive indices are constrained by the equations as follows to make low slope and low dispersion and higher effective area during C and L band transmissions.

$$n_1 > n_3 > n_4 > n_2$$

$$0.008 > (n_1 - n_4) > 0.007$$

$$0.0018 > (n_3 - n_4) > 0.0014$$

$$-0.0005 > (n_2 - n_4) > -0.0007$$

The optical fiber disclosed herein above and illustrated in accompanied figures 2a and 2b is insensitive to micro bend loss and dispersion slope no more than 0.08 ps/nm^2.km.

In a specific embodiment of the present invention the optical fiber shown in figure 2a has

$$(n_1 - n_4) = \text{about } 0.007$$

$$(n_3 - n_4) = \text{about } 0.0016$$

$$(n_2 - n_4) = \text{about } -0.0006$$

The presently disclosed optical fiber of figure 2a is also identified by the radius of each of the said parts, that is of the center core 1, cladding 2, ring core 3 and outer glass 4 are identified by the symbols a_1, a_2, a_3, and a_4 respectively and in accordance with the present invention, these radii are so selected that the dispersion and chromatic dispersion slope, and the bend loss during C- and L-band transmissions are in the desired range, and according to the present invention these radii are restricted by the following equations:

a_1 = about 2.7 um

a_2 = about 6.3 um

a_3 = about 8.8 um

In one illustrative embodiment of the present invention the refractive index profile of the optical fiber shown in figure 2a comprises single annular ring 2 of germanium and fluorine doped material

between a germanium doped center core 1 and-ring core 3. The outer pure glass 4 is provided onto the outer periphery of the germanium doped ring core 3.

In accordance to the present invention the optical fiber shown in figure 2a having a refractive index profile and relative radius of each of the said part as disclosed hereinabove has been identified having following characteristics:

Attenuation at 1550 nm	≤ 0.22
Dispersion at 1530 to 1565 nm	2.2 to 6.0 ps/nm.km
Dispersion at 1565 to 1625 nm	4.0 to 11 ps/nm.km
Dispersion slope (typical)	0.07 ps/nm^2.km
Polarization Mode Dispersion (PMD)	≤ 0.1 ps / km$^{0.5}$
Mode Field Diameter (MFD)	9.6 ± 0.4 um
Cut off wavelength (cable)	≤ 1280 nm
Core concentricity	< 0.6 um
Effective area (typical)	70 micron^2
Micro bending (Pin array)	< 0.05 dB at 1550 and 1625 nm
Macro bending (single 32 mm mandrel and 100 turns at 60 mm mandrel)	< 0.5 dB at 1550 and 1625 nm
Proof test	100 kpsi

In accordance to the present invention, Fig 4 discloses the chromatic dispersion characteristics of the fiber shown in figure 2a. It also shows how waveguide dispersion controls the low dispersion and low dispersion slope of the fiber.

The waveguide dispersion is given by the following equation

$$\frac{n_2\Delta}{c}\frac{1}{\lambda}\left[V\frac{d^2(Vb)}{dV^2}\right]$$

Where lambda is the wavelength of the light, b is the normalized propagation constant and c is the velocity of the light. The broken curve of figure 3 represents the waveguide dispersion characteristics of the fiber with ($n_1 - n_4$) = about 0.007, ($n_3 - n_4$) = about 0.0016, ($n_2 - n_4$) = about-0.0006, a_1 = about 2.7 um, a_2 =about 6.3 um and a_3 = about 8.8 um in accordance to the following invention.

Nonlinear effects arises in the fiber due to small dependence of the refractive index on power, known as the Kerr effect:

$$N_1 = N_0 + N_L P/A_{eff}$$

Where, N_0 is the index of refraction, N_L is nonlinear index of refraction and P is the intensity of the light in the fiber. The above equation infers that larger effective area helps lower the penalties due to non-linearities. It is very difficult to achieve larger effective area without affecting the other fiber parameters like dispersion slope, dispersion and bending performances. This is the fact that the design characteristics of the above invention is an exemption which can optimized the fiber with higher effective area, Lower dispersion slope and low micro bend sensitivity. Effective are is one of the characteristics of the fiber which directly related to the mode field diameter. The modal field extends far into the cladding for fiber shown in figure 4. Thus Mode Field Diameter (MFD) is very different from core diameter. That's why MFD rather than core diameter is an important parameter. Fig 4 discloses the intensity field distribution, overlapped on the refractive index profile of fiber, across the diameter of the fiber.

Dated this 22nd day of January, 2003.

(DR. RAMESH KUMAR MEHTA)
of Remfry & Sagar
Attorney for the Applicants

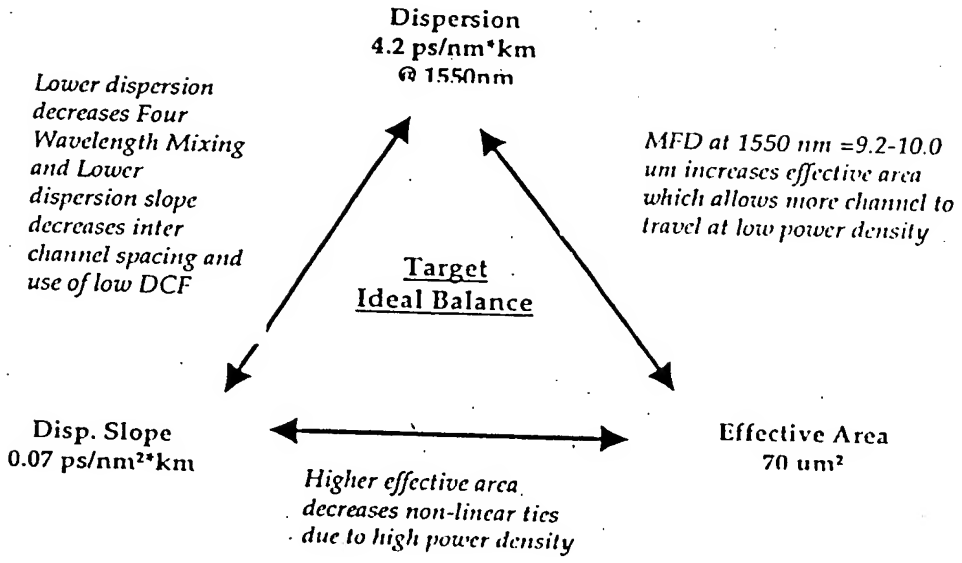


Fig 1

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of Remfry & Sagar
Attorney for the Applicants

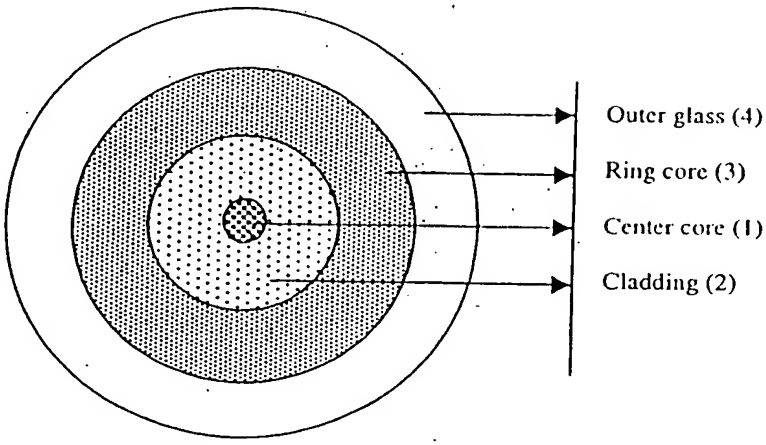

Fig. 2a

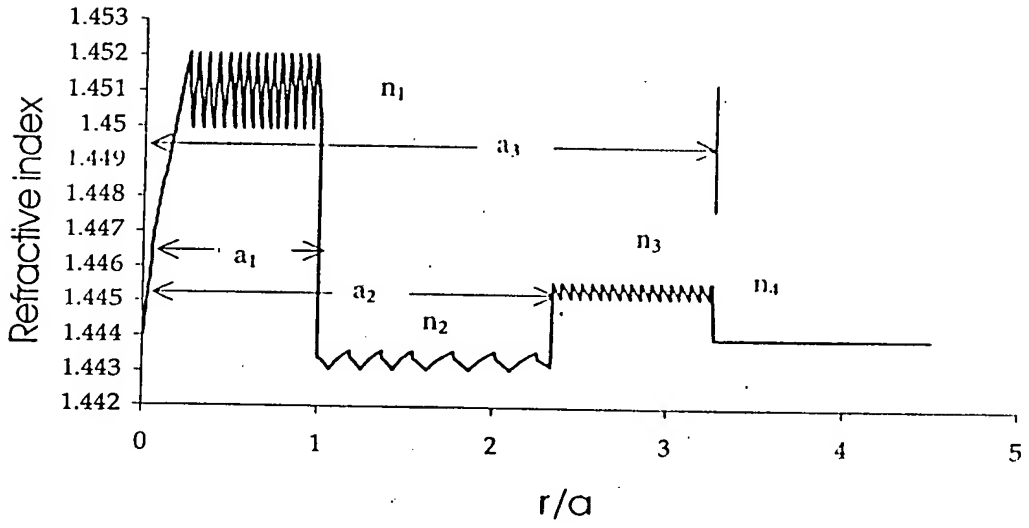

Fig. 2b

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of Remfry & Sagar
Attorney for the Applicants

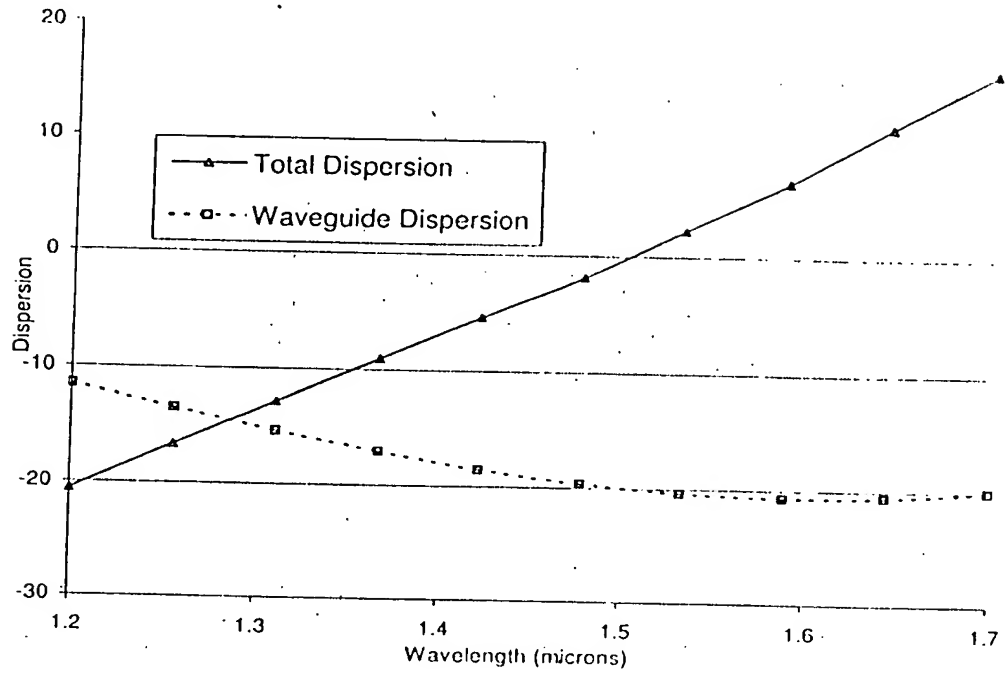

Fig. 3

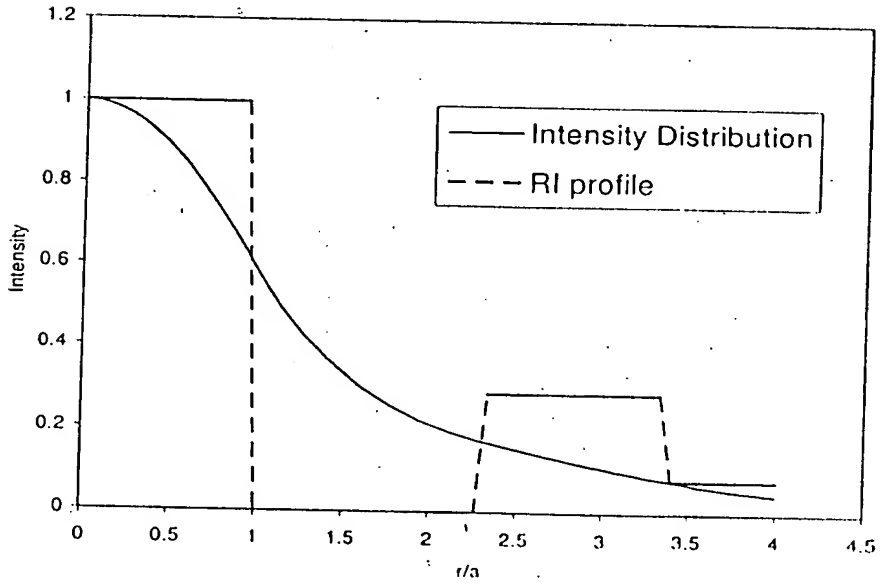

Fig. 4

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